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Fractures system within Qusaiba shale outcrop and its relationship to the lithological properties, Qasim area, Central Saudi Arabia

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A B S T R A C T

The basal Qusaiba hot shale member of Qalibah Formation is considered to be an important source rock in the Paleozoic petroleum system of Saudi Arabia and an exploration target for tight shale as one of the Unconventional resources of petroleum. This work has been carried out to understand the fractures network of Qusaiba shale member in outcrops located to the west of Qusayba' village in Al-Qasim area, Central Saudi Arabia. The main objective of this study is to understand the distribution of natural fractures over different lithological units. Description data sheets were used for the detailed lithological description of Qusaiba shale member on two outcrops. Spot-7 and Landsat ETM+ satellite images were used for lineament mapping and analyses on a regional scale in a GIS environment. Fractures characterization in outcrop-scale was conducted by using linear scanline method. Qusaiba shale member in the study area consists of 5 main lithofacies, divided based on their sedimentary structures and petrographical properties, from base to top in the outcrops, the lithofacies are; fissile shale, very fine-grained micaceous siltstone, bioturbated mudstone, very fine to fine-grained hummocky cross-stratified sandstone, and fine to medium-grained low/high angle cross-stratified sandstone lithofacies. Lineaments interpretation of the Spot-7 and Landsat ETM+ satellite images showed two major directions in the study area; 320° that could be related to Najd fault system and 20° that could be related to the extensional activities which took place after Amar collision. Fractures are much denser in the fissile shale and mudstone lithofacies than sandstones lithofacies, and average spacing is smaller in the fissile shale and mudstone lithofacies than sandstones lithofacies. Lineaments and large-scale fractures are Non-Stratabound fractures and they deal with the area as one big mechanical unit, but small-scale fractures are Stratabound fractures that propose different mechanical units within Qusaiba shale member in the study area. The fractures network in the study area has a wide range of properties related to fractures density, length, spacing, height, and termination degree. The conceptual multi-scale model divides the fractures in the study area into 4 orders depending on the available data that have been observed from satellite images and field. The multi-scale fractures model that was generated in this study could help to understand the distribution of stratigraphically controlled fractures when integrated with flow simulation models. Overall, this work could have a significant contribution to tight shale exploration plans in the subsurface by providing some knowledge about the fractures mechanical behavior of the lower part of Qusaiba shale member of Qalibah Formation.

1. Introduction

Fractures can majorly impact the flow of fluids within hydrocarbon reservoirs by increasing the permeability of the rocks if they are open, or by decreasing the permeability of the rocks if they are filled with a cementing material (Laubach et al., 2009). Connectivity of fracture system highly controls the fluids flow. The permeability

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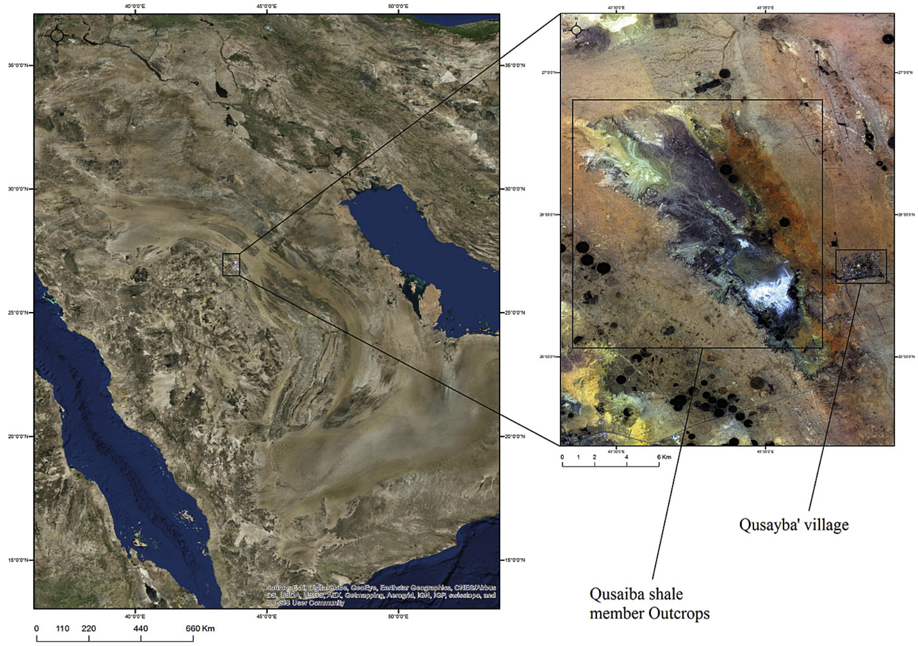

Fig. 1. Satellite images showing the Location of the study area in Central Saudi Arabia.

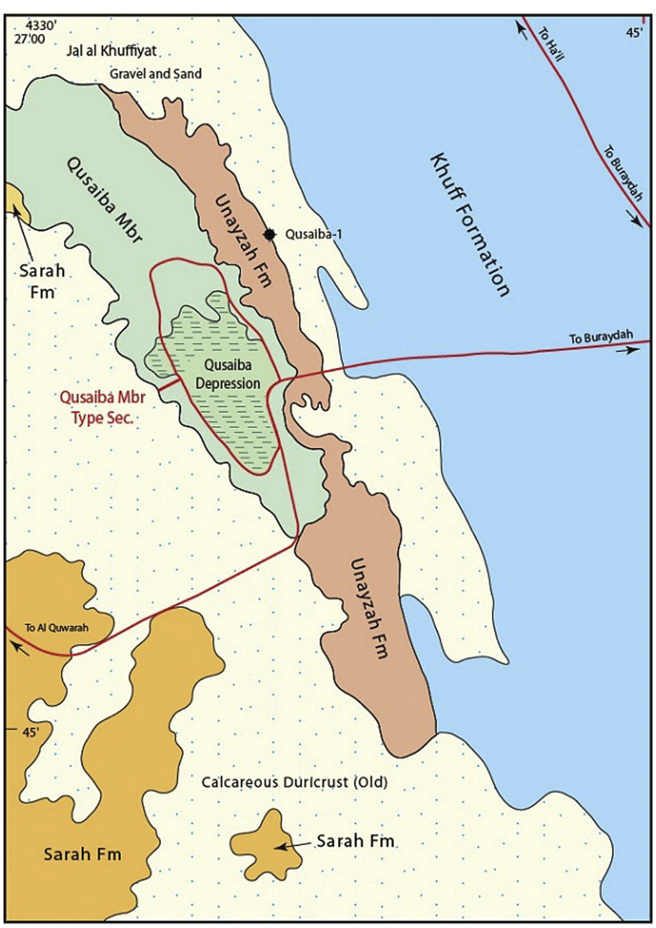

Fig. 2. Type Section Locality of Qusaiba member in Qusaiba depression - Qasim area, Central Saudi Arabia (Manivit et al., 1986).

for a reservoir is based on the density and orientation of fractures (Odling et al., 1999). Outcrop analog studies of fractures provide information on different scales (Strijker et al., 2012) and could be calibrated with sub-surface data if found (Laubach et al., 2009). This could provide important multi-scale information about the nature of the fractures, and how could it influence the production strategy of a reservoir (Bertotti et al., 2007). There are two end-member types of fractures based on the influence of the lithological layers; Stratabound and Non-Stratabound (Odling et al., 1999). Literature shows that the data of the fracture systems in outcrop analogs are commonly acquired from remotely sensed images or fieldwork data in the form of 2D sub-horizontal or sub-vertical maps of fracture traces. Fracture maps are statistically analyzed for specific attributes such as; length, aperture, intensity or spacing, and shape, which can be used to characterize fractures (Odling et al., 1999). Fracture spacing in a rock mass is controlled by several geological parameters; composition, grain size, porosity, lithological layering, and structural position (Nelson, 2001). The concept of a fracture unit was introduced based on the fact that in well-stratified sequences, fractures are of systematic confinement to a single or a combination of several sedimentary layers (Underwood et al., 2003; Bertotti et al., 2007). Fracture unit is a package of one or more sedimentary layers with a relatively homogeneous fracture attribute distribution, commonly vertical extent or spacing. Fracture unit thickness is a key component in most models of fracture growth and fracture-pattern development (Laubach et al., 2009). Three principal fracture modes are defined in the literature based on the displacement vector and fracture propagation direction; Mode I, Mode II, and Mode III. Mode I represents the opening displacement fractures and is perpendicular to the surface of the fracture. Mode II and Mode III represent the shearing displacement fractures, where Mode II fractures are perpendicular, and Mode III fractures are parallel to the surface of the fracture (Nelson, 2001). Mode I is usually described as joints or fractures, and Mode II and Mode III are usually described as faults (Pollard and Aydin, 1988). Regional fracture systems develop over wide areas with almost no change in orientation, they are